CHAPTER 7
CULVERTS AND BRIDGES

7.1 Introduction

As used in this manual, bridges are defined as structures 20’ wide or greater (support to support) that transport vehicles over streams or constructed channels. Culverts are structures narrower than 20’ wide that transport vehicles over streams or constructed channels.

7.2 Culvert Design Criteria

7.2.1 General

Culverts shall be located and designed to present a minimum hazard to traffic and people.

7.2.2 Alignment and Slope

The culvert shall be designed to approximate the existing alignment and slope of the stream.

A culvert shall not be placed within 50 feet of a bend in a stream or channel greater than 20 degrees.

7.2.3 Allowable Headwater

The culvert shall be designed so that:

- HW/D (headwater/barrel height) is no greater than 1.2 for the 100-year storm for drainage areas less than or equal to one square mile
- HW/D is no greater than 1.0 for the 100-year storm for drainage areas greater than one square mile
- The headwater is at least 12 inches below the edge of pavement for the 100-year storm
- The headwater is at least 24 inches below the lowest opening of upstream structures for the 100-year storm

7.2.4 Culvert Size and Shape

A minimum culvert diameter of 15 inches shall be used to avoid maintenance problems and clogging.

7.2.5 Multiple Barrels and Staged Culverts

Culverts with a drainage area of greater than 1.0 square miles shall be designed using multiple barrels at different elevations according to the following:

- Develop a stage-discharge curve for the existing floodplain to determine the discharge associated with bank full flow and the flow distribution for events greater than bank full flow.
- Design the culvert pipe within the main channel to pass bankfull flow as a minimum.
- Where practical, use additional barrels in the floodplain so that the flow distribution after construction of the culverts approximates the distribution prior to construction. For example, if 30 percent of the 100-year storm passes through the main channel cross-section with 35 percent passing in the floodplain on each side, use staged culverts to approximate that distribution.

7.2.6 Culvert Skew

A culvert shall be designed with a maximum skew of 45 degrees as measured from a line perpendicular to the roadway centerline.

7.2.7 End Treatments

All culverts shall be designed with inlet and outlet headwalls. The parapet wall shall be parallel to the road.

7.2.8 Outlet Protection

The outlet of culverts shall be protected with gabion mattresses or impact stilling basins in accordance with Chapter 11.

7.3 Culvert Design Procedures

7.3.1 Approved Methods

Culverts shall be designed in accordance with methods described in "Hydraulic Design of Highway Culverts" (Hydraulic Design Series (HDS) No. 5) of the Federal Highway Administration (FHWA). HDS No. 5 is based on the concept of analyzing a culvert for both inlet and outlet control and designing for the control that produces the minimum performance.

7.3.2 Inlet Control

Inlet control occurs when the culvert barrel is capable of conveying more flow than the inlet will accept. For inlet control, the control section is at the upstream end of the barrel (the inlet). The flow passes through critical depth near the inlet and becomes shallow, high velocity (supercritical) flow in the culvert barrel. Depending on the tailwater, a hydraulic jump may occur downstream of the inlet.

Factors which affect the flowrate for a given headwater depth during inlet control are inlet area, inlet edge configuration and inlet shape. The following definitions are important for inlet control:

- The control section is the location where there is a unique relationship between the flow rate and the upstream water surface elevation.
- Headwater depth is measured from the inlet invert of the inlet control section to the surface of the upstream pool.
- Inlet area is the cross-sectional area of the face of the culvert. Generally, the inlet face area is the same as the barrel area.
- Inlet edge configuration describes the entrance type. Some typical inlet edge configurations are thin edge projecting, mitered, square edges in a headwall, and beveled edge.
- Inlet shape is usually the same as the shape of the culvert barrel. Typical shapes are rectangular, circular, elliptical, and arch.

7.3.3 Outlet Control

Outlet control occurs when the culvert barrel is not capable of conveying as much flow as the inlet opening will accept, and the downstream end of the culvert controls the flow. Outlet control has depth and velocity that are subcritical. The tailwater depth is either assumed to be critical depth near the culvert outlet or the downstream channel depth, whichever is higher. In addition to the inlet control factors, the following factors also affect outlet control flow:

Barrel Roughness

Barrel roughness is a function of the material used to fabricate the barrel. The roughness is represented by a hydraulic resistance coefficient such as the Manning n value.

Barrel Area and Shape

Barrel area is measured perpendicular to the flow. Barrel shape impacts the friction loss through the barrel.

Barrel Length

Barrel length is the total culvert length from the entrance to the exit of the culvert. Because the design height of the barrel and the slope influence the actual length, an approximation of barrel length is usually necessary to begin the design process.

Barrel Slope

Barrel slope is the actual slope of the culvert barrel, and is often the same as the natural stream slope. However, when the culvert inlet or outlet is raised or lowered, the barrel slope is different from the stream slope.

Tailwater Elevation

Tailwater is based on the downstream water surface elevation. Backwater calculations from a downstream control, a normal depth approximation, or field observations are used to define the tailwater elevation.

7.4 Bridge Design Criteria

7.4.1 General

Bridges shall be designed to:

- pass the 100-year flow with one foot of freeboard below the bottom of the bridge structure
- not damage the road or increase damages to adjacent property because of high velocities
- maintain existing flow distribution in the floodplain to the extent practicable
- minimize flow disruption and potential scour from pier spacing, pier orientation, and abutment
- avoid failure by scour
- pass anticipated debris
- provide measures to counteract the sometimes unstable or unpredictable nature of alluvial streambeds or demonstrate that the risk of damage is low
- produce minimal disruption of ecosystems and values unique to the floodplain and stream
- accommodate pedestrian access

7.4.2 Backwater Increases

Bridges shall be designed so that flooding to upstream properties is not increased over existing levels. Verify this by conducting a flow profile analysis for the waterway, using the 100-yr storm flow, for conditions prior to and following construction of the bridge. Limit the allowable increase in backwater at the bridge to 1 foot during passage of the 100-yr flow.

7.5 Bridge Design Procedures

Use HEC-RAS to evaluate the effects of the bridge.

7.6 Construction Specifications

7.6.1 Circular Culvert Pipe

Circular culvert pipe shall be reinforced concrete pipe and shall be installed in accordance with the LFUCG Standard Drawings and KYTC Standard Specifications for Road and Bridge Construction, latest edition.

7.6.2 Box Culverts

Box culverts shall be constructed in accordance with the LFUCG Structures Manual.